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A Study on the Effect of MACCS Plume Rise Models on the Off-Site Consequence

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1. Introduction

A research project has been conducted since 2019 to verify that the facilities handling radioactive materials on the Korea Atomic Energy Research Institute (KAERI) site are satisfied with the domestic nuclear safety goals through the research site risk profile assessment. A risk profile can be obtained from the full scope of level 1/2/3 Probabilistic Safety Assessment (PSA) [1]. A preliminary MACCS2 (MELCOR Accident Consequence Code System 2) input model has been developed for the level 3 PSA on the KAERI site in the previous study [2]. One of the important things is a parametric study to confirm the relative importance of each input variables for site-specific consequence analysis.

This paper focuses on the analysis of the effect of the plume rise model that is one of the important inputs of the atmospheric dispersion model in MACCS2.

2. A Comparison Study on Plume Rise Models for Research Site Consequence Analysis

There are three components of MACCS plume rise models, as follows [3].

① Plume liftoff from a building wake
② Plume rise under stable atmospheric condition
③ Plume rise under unstable and neutral atmospheric conditions

Buoyant plume rise ends when any of the following conditions occur [3].

① When plume reaches a final rise height
② When plume centerline reaches the mixing height
③ When one hour has elapsed from the time plume emission started

There are two plume rise models in MACCS2, which are the original and improved MACCS plume rise model. In the original MACCS plume rise model, Briggs plume rise equation (Briggs, 1975; Hanna, 1982) was used to calculate the final height of plume rise for stable, neutral, and unstable atmospheric conditions. The improved MACCS plume rise model is also based on Briggs, but slightly modified version was applied. In MACCS2, there are two input options to determine plume buoyancy, which are Power model and Density and flow model. When applying Power model, the release rate of sensible heat content of plume is used as input parameter to calculate plume buoyancy. In case of applying Density and flow model, the rate of mass release and a density of plume segment are used in calculation.

Input parameters of MACCS2 for the KAERI site were obtained from the previous study [2]. Analysis of accidents at HANARO and Post Irradiation Examination Facility (PIEF) has been carried out in our research project. Preliminary source term data for Beam Tube Break (BTLOCA) accident scenario at HANARO [4] and cold-gap accident scenario at PIEF were obtained from the calculation result of MELCOR performed in this research project. MACCS/ WinMACCS version 4.0.0 [5] was used in this study.

3. Results and Discussions

To analyze the effect of MACCS plume rise models on the off-site consequence, the calculations were performed on ground-level air concentrations of radionuclide for hypothetical accident scenarios at PIEF and HANARO. Figure 1 and 2 show Cs-137 ground-level air concentrations (Bq·s/m^3) of PIEF and HANARO accident cases.

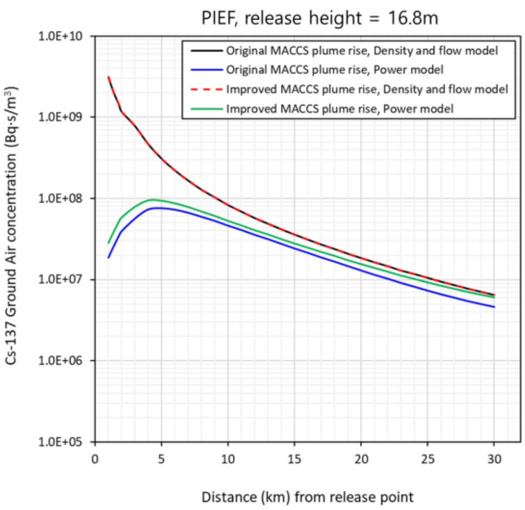
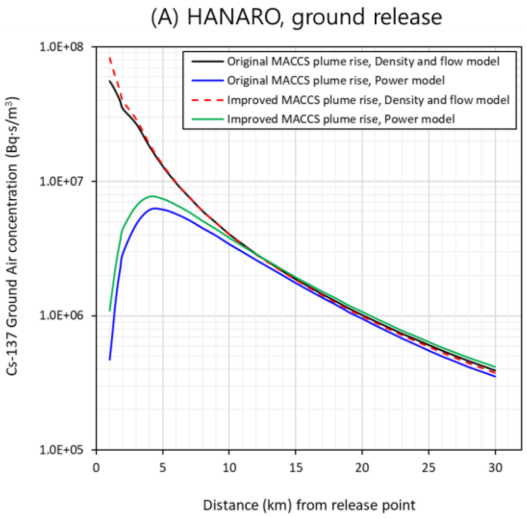


Fig.1. Ground air concentration (Bq·s/m^3) of Cs-137 for a hypothetical accident scenario at PIEF (mean value)



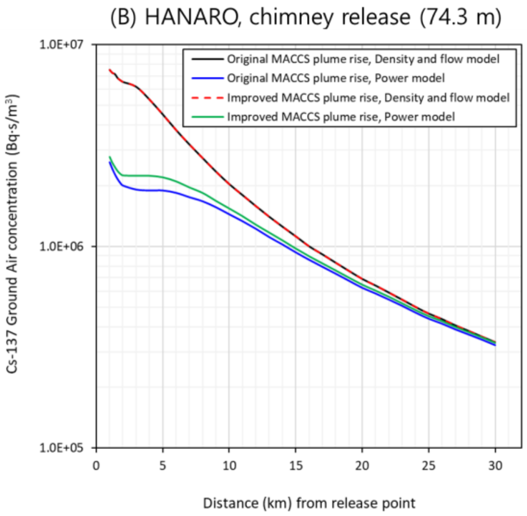


Fig.2. Ground air concentration (Bq·s/m^3) of Cs-137 for hypothetical accident scenarios at HANARO (mean value). (A) Ground release (B) Chimney release at 74.3m

Ground-level air concentration (Bq·s/m^3) represents the centerline ground-level integrated air concentration from the plume segment averaged over the spatial interval's length.

In both cases of PIEF and HANARO, ground-level air concentrations of Cs-137 were evaluated the highest when density and flow model of the original and improved MACCS plume rise model was applied. The difference between the results for each applied model decreases as the distance increased. Table 1 shows the calculation results of the final rise height reached by the plume segment under each plume rise model.

Table 1. Final rise height of plume segment depending on MACCS plume rise model

Final rise height of plume segment (m)	Original MACCS plume rise model		Improved MACCS plume rise model	
	Density and flow model	Power model	Density and flow model	Power model
PIEF	1.79E+01	4.85E+02	1.79E+01	2.20E+02
HANARO (ground release)	7.84E+01	4.65E+02	1.46E+01	2.08E+02
HANARO (chimney release)	7.43E+01	2.64E+02	7.43E+01	1.45E+02

In case of applying density and flow option of the improved MACCS plume rise model, the final rise height of plume segment was the lowest for every accident cases. In the calculation applying this model, Cs-137 air concentration at the ground-level was evaluated the highest as shown Figure 1 and 2. However, the concentrations of Cs-137 deposited on the ground and the off-site consequences did not show a specific trend according to the selection of the plume rise models.

4. Conclusion

This study was conducted to determine whether the atmospheric dispersion results and the off-site consequences applied with a specific plume rise model tend to overestimate or underestimate compared to other models. Since the results are complicatedly affected by the various models and input parameters in the calculation process, it is difficult to conclude that the specific plume rise model influences the evaluation result to show certain trend. These results should not be generalized for every case of the nuclear accidents, since only the limited calculations were performed for hypothetical accidents at HANARO and PIEF with KAERI-specific data. This work will be used as basic material for our research project.

ACKNOWLEGEMENT

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